Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 75 (2015) 1654 – 1658

Energy Procedia

The 7th International Conference on Applied Energy – ICAE2015

Influence from the Dual Phase Heat Exchanger on the Performance of A Combined Thermal System

Weifeng He *, Dong Han , Chen Yue , Wenhao Pu

Nanjing University of Aeronautics and Astronautics, Jiangsu Province Key Laboratory of Aerospace Power Systems, No. 29, Yudao Street, Qinhuai District, Nanjing 210016, China

Abstract

An air-cooled organic Rankine cycle (ORC) is applied to condense turbine exhaust of the steam Rankine cycle, thus a combined thermal system is established to achieve the cascade utilization of the energy. As a result, the condenser of the steam cycle is simultaneously used as the evaporator for the ORC system, which is called the dual phase heat exchanger (DPHE), and then the working fluid, R245ca, from the ORC turbine is condensed by the ambient air. Obviously, the performance of the DPHE is critical for the characteristics of the ORC cycle and the combined thermal system. The performance of the combined cycle is calculated at different temperature difference of the DPHE, and the relevant principles are also demonstrated.

Peer-review under responsibility of Applied Energy Innovation Institute

Keywords: organic Rankine cycle; combined thermal system; dual phase heat exchanger; temperature difference

1. Introduction

Thermal power plants are extensively developed to supply the electricity and heat simultaneously, and the back pressure steam turbines or extraction turbines are generally equipped in the combined heat and power system. As a result, both the power load and the heat load should be fully considered in the type of thermal power plant [1], and for the turbine, it is a real challenge to have a high efficiency when the heat load is deficient, and it is significant to recover the energy from the turbine exhaust because the back pressure is quite high for such back pressure turbines.

Meanwhile, organic Rankine cycle, in which the substance with lower boiling point is treated as the working fluid, is regarded and proved as an excellent scheme to recover the low grade heat recent years [2-4]. Liu [5] presents a cogeneration system in which a back pressure steam turbine generating unit is coupled with an organic Rankine cycle. R113 is selected as the working fluid in the ORC cycle, and the performance of the ORC system is investigated at the rating condition of the

Peer-review under responsibility of Applied Energy Innovation Institute
doi:10.1016/j.egypro.2015.07.403

steam cycle.

He [6] proposed a combined heat and power system with an air-cooled organic Rankine cycle (ORC). The performance of the combined thermal system is calculated, and the single and double recuperation are applied to raise the system performance. Furthermore, the variational condition performance of the air-cooled ORC condenser at different ambient temperatures is also calculated. However, as the evaporator of the ORC, the influence from the dual phase heat exchanger on the performance of the ORC and the combined thermal system is not investigated. In the current paper, the temperature difference of the DPHE is aimed to investigate the mentioned influence. The research results provide the significant references for the design and optimization of the combined thermal system.

Nomenclature

h	heat transfer coefficient of the air-cooled condenser, w/(K·m^2)
m	mass flow rate, kg/s
p	pressure, MPa
T	temperature, K
TD	temperature difference, K
W	output power of the turbine, kW
Q	heat duty of the boiler, kW
η	efficiency
Subscripts	
a	air
bp	back pressure
c	consumption
p	pump
r	recuperation
ref	reference
s	steam
t	total, turbine

2. Combined thermal system

The combined thermal system with steam Rankine cycle and organic Rankine cycle is constructed and presented in Fig. 1. It is seen that two thermal cycles are connected through the dual phase heat exchanger, and the turbine exhaust is applied to heat the organic working medium, which evaporates to drive the turbine in the ORC system. Furthermore, recuperation is used to preheat the working fluid into the steam generator for a higher efficiency of the thermal system, and the recuperative heat exchangers are both arranged in the steam cycle and ORC, respectively.

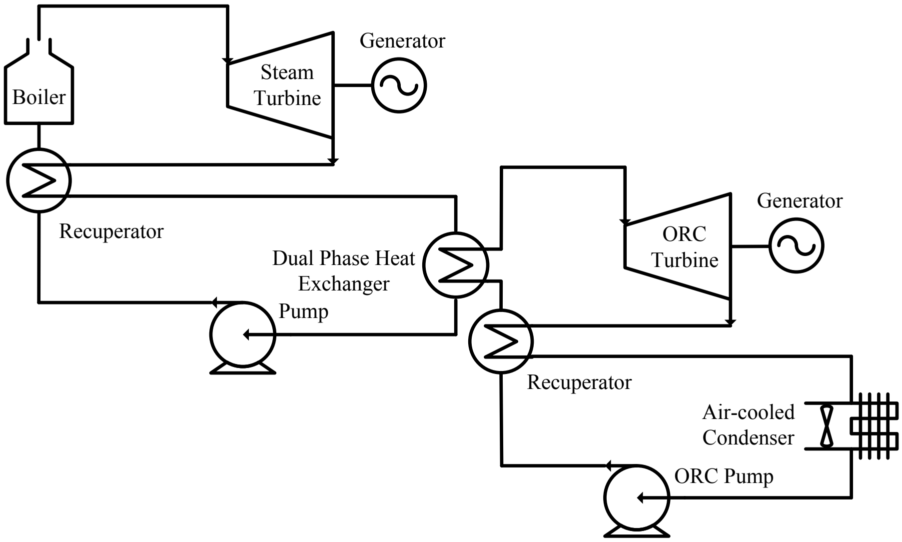

Fig.1 Scheme and layout of the involved combined thermal system

3. Analysis and discussion

The current investigation aims to investigate the influence from the performance of the dual phase heat exchanger on the characteristics of the ORC system and the combined thermal system. Before the analysis, it is necessary to make some assumptions to simulate the performance of the thermal cycle, and the relevant parameters are listed in Table. 1.

Table 1 Assumed parameters for the combined thermal system

Parameters in the combined thermal system	value
p_s, MPa	1.27
T_s, K	613
m_s, kg/s	1.88
TD_r, K	4
TD_c, K	15
p_c, MPa	0.22
m_{ORC}, kg/s	17.9
T_a, K	306
η_t, %	0.8
η_p, %	0.85
m_{aref}, kg/s	537.5
h_{ref}, w/(k·m^2)	33

Furthermore, it is assumed that the working fluid into the ORC turbine is saturated. The temperature difference of the dual phase heat exchanger, defined as the difference between the outlet of the hot condensate water and the cold evaporated organic vapor, is selected to investigate the influence on the performance of the ORC system and the combined thermal system. It is inferred that from the above table, the total absorbed heat from the steam generator and the power of the steam turbine is the same, with a value of 4602.3kW and 500kW respectively. The performance of the combined thermal system at five temperature difference of the DPHE is presented in Fig. 2, in which the ORC power and the thermal efficiency are listed respectively. It is found that the ORC power decreases from P_{ORC}=549.8kW to P_{ORC}=517.4kW, an amplitude of 5.9% when the temperature difference rises from TD_{DPHE}=3K to TD_{DPHE}=7K. Finally, the thermal efficiency of the thermal efficiency drops from 22.8% to 22.1%.

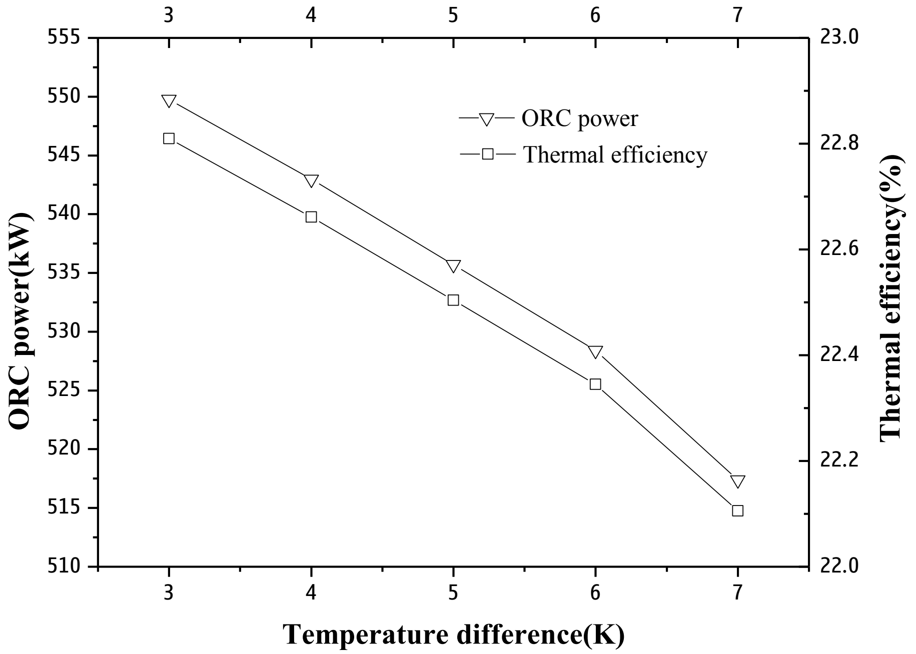

Fig.2 Performance of the combined thermal system at different temperature difference for the dual phase heat exchanger

It is obvious that the variation of the temperature difference for the dual phase heat exchanger will change the pressure of the ORC working fluid into the turbine, and the condition of the turbine will alternate. For example, the evaporative pressure of the organic working fluid will be decreased in response to the increase of the temperature difference, and then the output power of the ORC turbine is also reduced.

4. Conclusions

The obtained simulated results provide the references to solve the low performance of the general thermal power plants at deficient heat load period. As the connection of the general steam cycle and the ORC, the performance of the dual phase heat exchanger is very critical for the ORC and the combined thermal system. It is demonstrated that the ORC power as well as the final efficiency is reduced resulting from the increasing temperature difference. In the paper, the simple calculation process is obtained, and the more complicated optimization of the combined thermal system, with the temperature difference of the two recuperator and the DPHE will also be achieved in the future.

Acknowledgements

The authors gratefully acknowledge the financial support by the National Natural Science

Foundation of China (Grant No. 51406081).

References

[1] T. K. Zheng. *Thermal Power Plant*. Beijing, China Electric Power Press, 2008.

[2] C. R. Kuo, S. W. Hsu, K. H. Chang, C. C. Wang. Analysis of a 50 kW organic Rankine cycle system. Energy, 2011, 36 (10): 5877-5885.

[3] S. Quoilin, S. Declaye, B. F. Tchanche, V. Lemort. Thermo-economic optimization of waste heat recovery organic Rankine cycles. *Appl. Therm. Eng.*, 2011, 31 (14-15): 2885-2893.

[4] J. Sun, W. H. Li. Operation optimization of an organic Rankine oycle (ORC) heat recovery power plant. *Appl. Therm. Eng.*, 2011, 31 (11-12): 2032-2041.

[5] Q. Liu, Y.Y. Duan. Cogeneration system comprising back-pressure steam turbine generating unit coupled with organic Rankine cycle. *Proceedings of the CSEE*, 2013, 33: 29-36.

[6] W.F. He, D. Han, C. Yue, W.H. Pu. A Combined Thermal System with an Air-cooled Organic Rankine Cycle (ORC). ICAE 2014, 2014, Taipei.